University of Strathclyde
Advanced Space Concepts Laboratory

2011 International Workshop on Environment and Alternative Energy

Space-based geoengineering to counteract anthropogenic climate change

Russell Bewick

Contents

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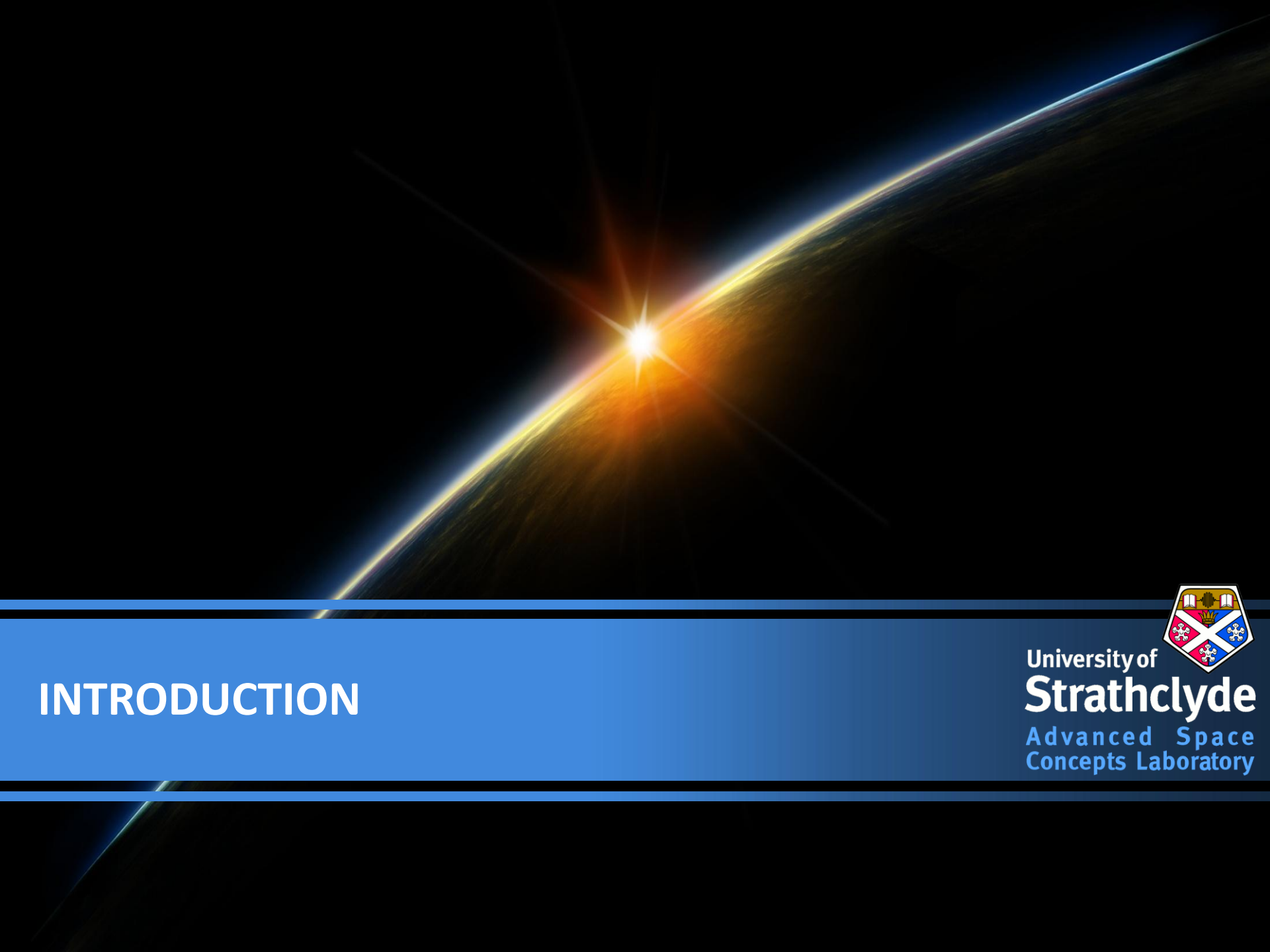
- Introduction
- Space-based geo-engineering
- Political environment
- A combined approach
- Conclusion



INTRODUCTION

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Why geo-engineer?

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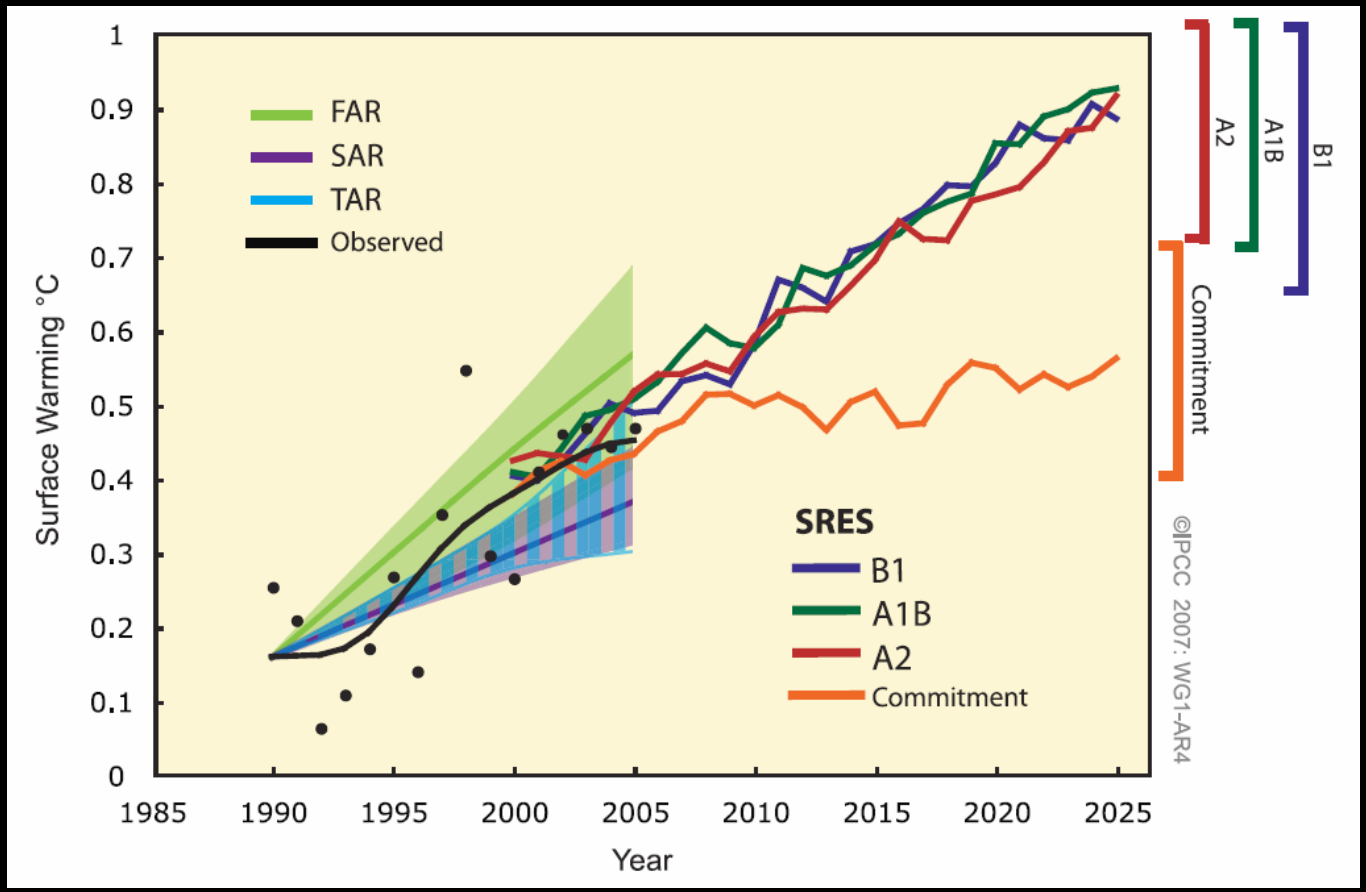
Fig. Mean global temperature prediction compared with observation



Solomon et al. (2007): Technical Summary. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change

Methods of geo-engineering

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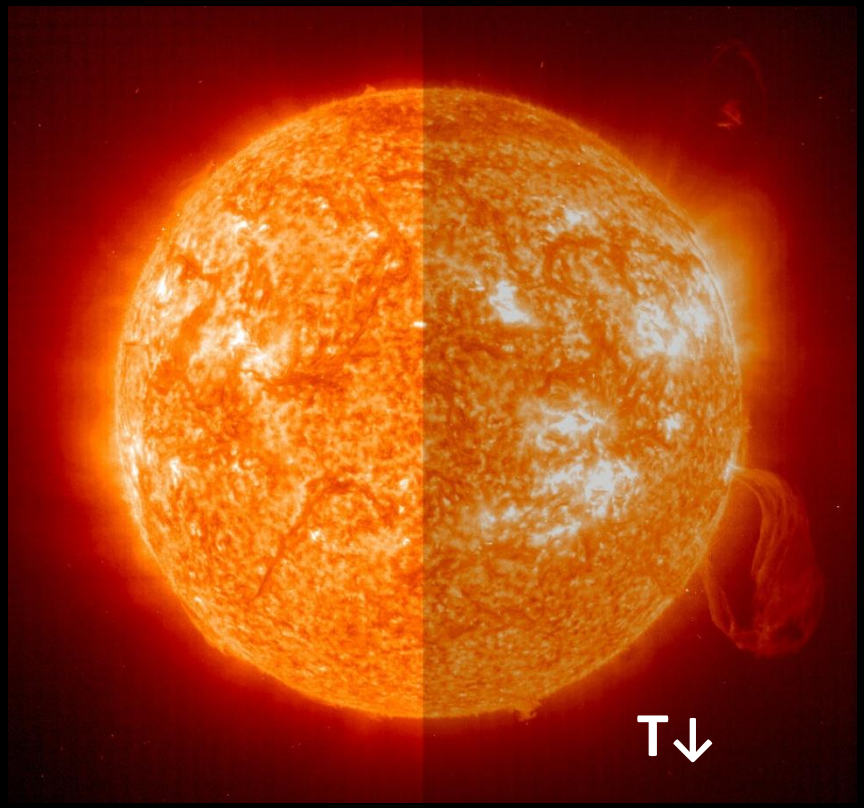
Solar Radiation Management



Carbon Capture

Methods of geo-engineering

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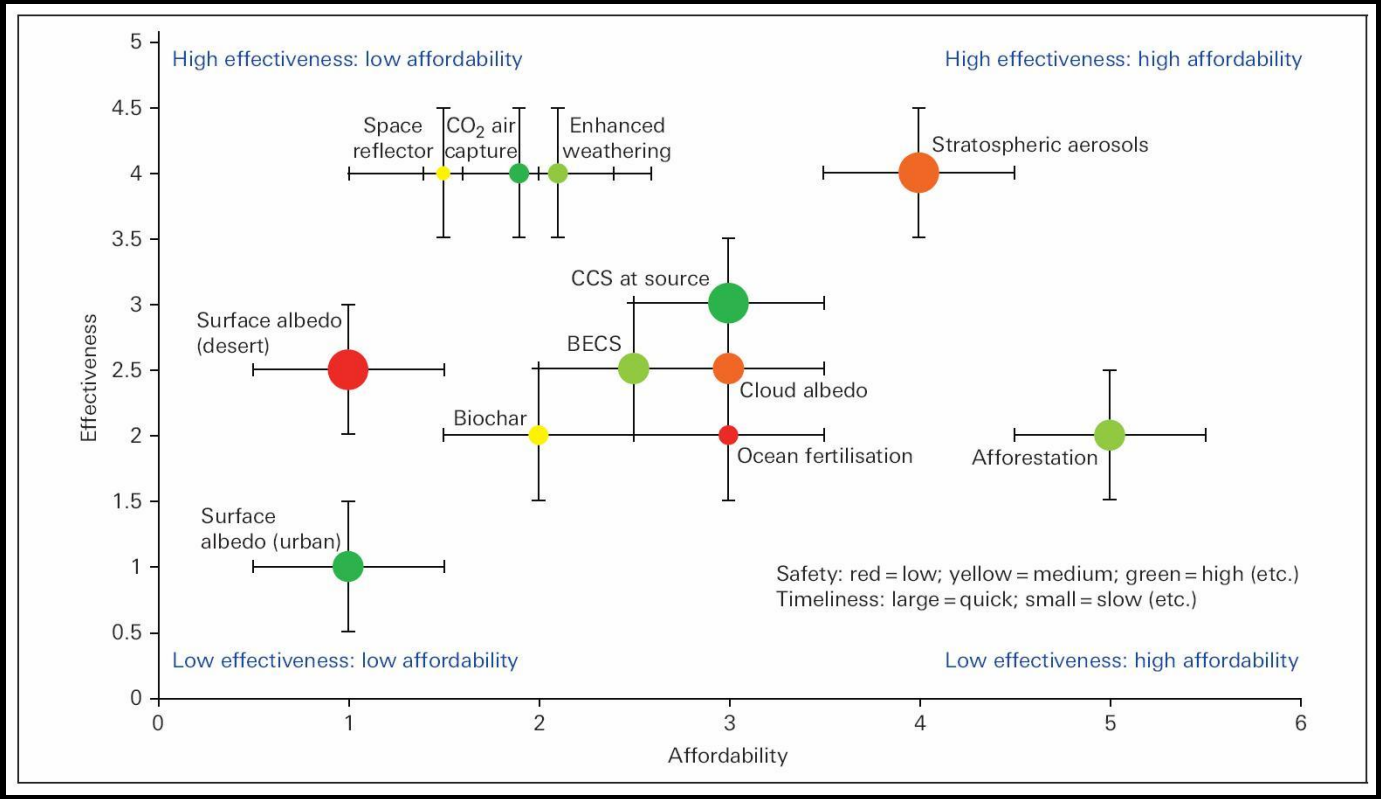
Fig. The effectiveness, affordability, safety and timeliness ratings of geoengineering methods analysed in a Royal Society report



Shepherd at al. Geoengineering the climate , Report of Royal Society working group on geoengineering, 2009

SPACE-BASED GEO-ENGINEERING

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Previous Proposals

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Aim: reduce solar flux by 1.7%

Previous Proposals

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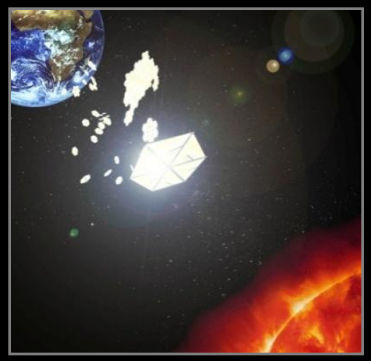
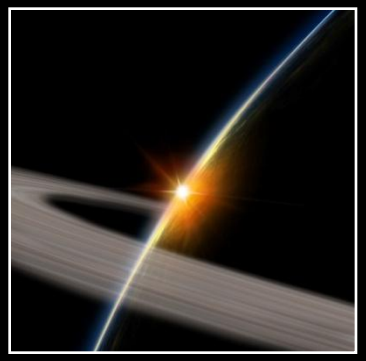


Reflectors



Dust

Aim: reduce solar flux by 1.7%

Previous Proposals

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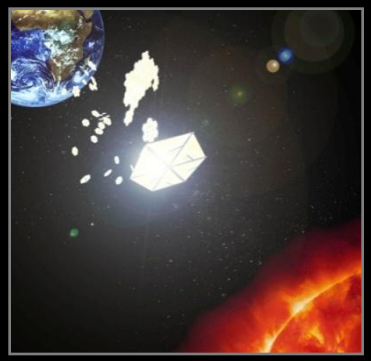
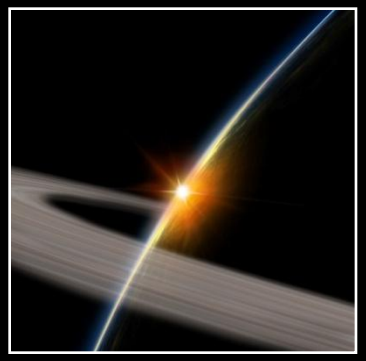
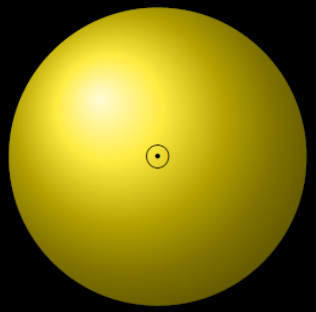


Reflectors



Dust

Aim: reduce solar flux by 1.7%



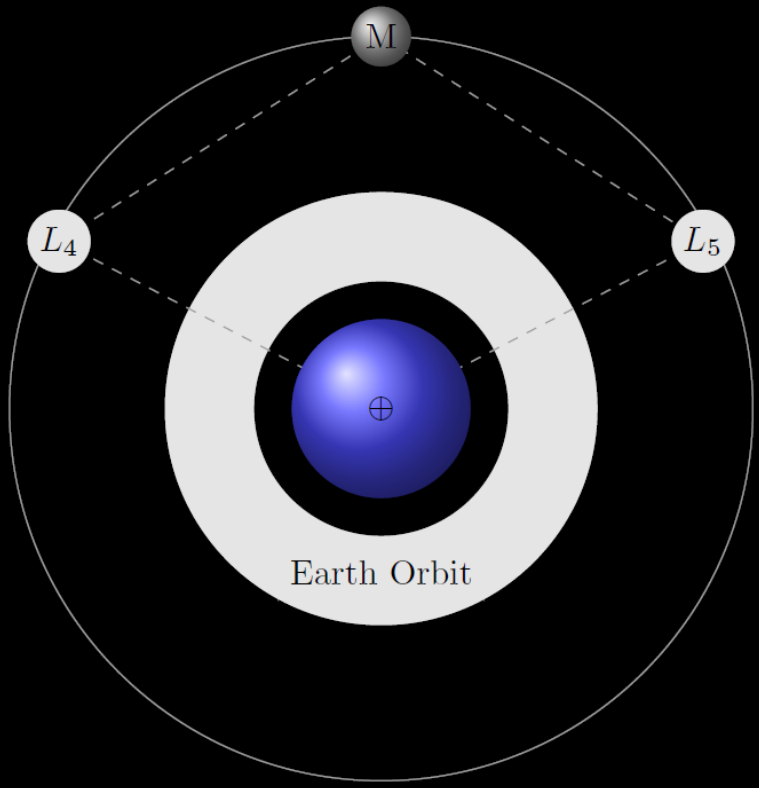


Fig. 3: Positions of the proposed geoengineering methods

Research Aim

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- Reduce complexity
- Reduce cost
- Increase timeliness

Research Aim

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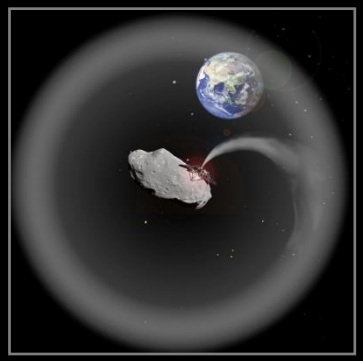
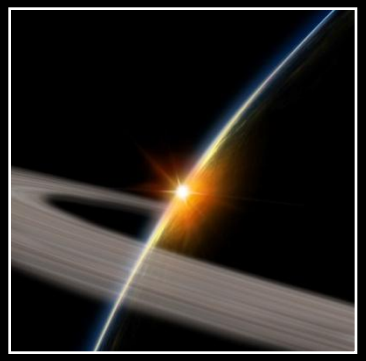
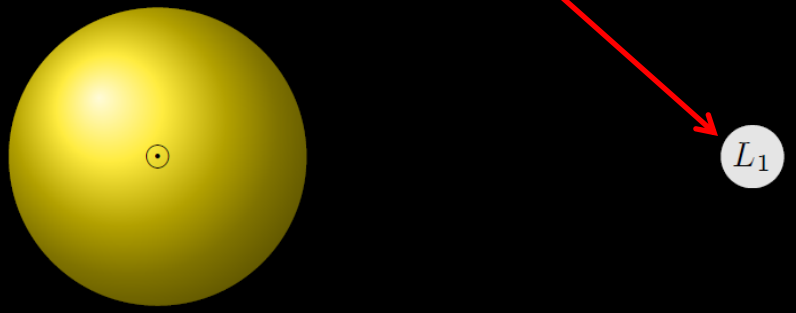


L_1 Dust Cloud



Earth Dust Ring

Aim: reduce solar flux by 1.7%



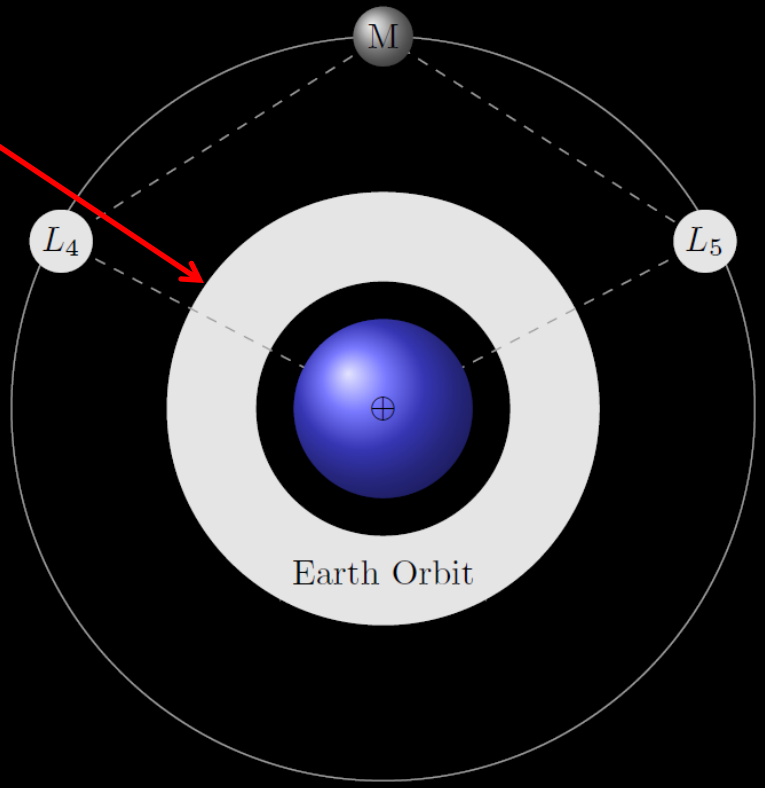


Fig. 3: Positions of the proposed geoengineering methods

L_1 Dust Cloud – Scenario

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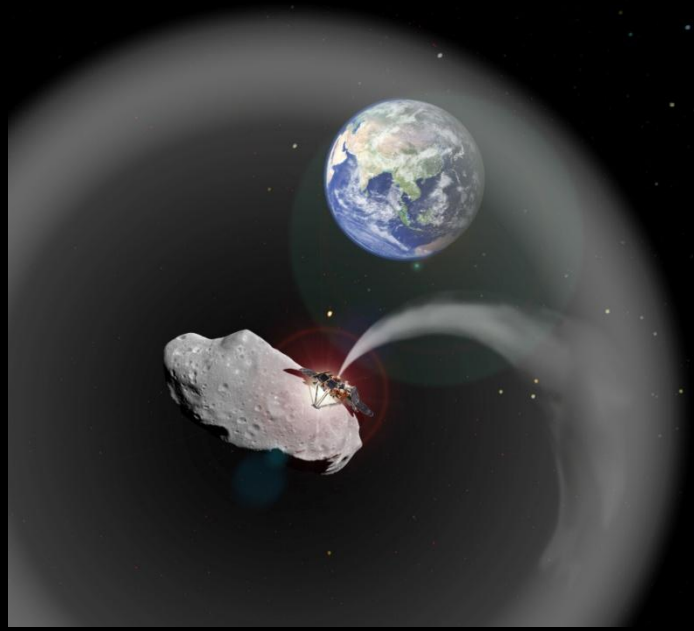
Capture NEO

Mine and eject dust

Insolation reduction

Dust drifts away

Create steady state



L_1 Dust Cloud – Dynamics

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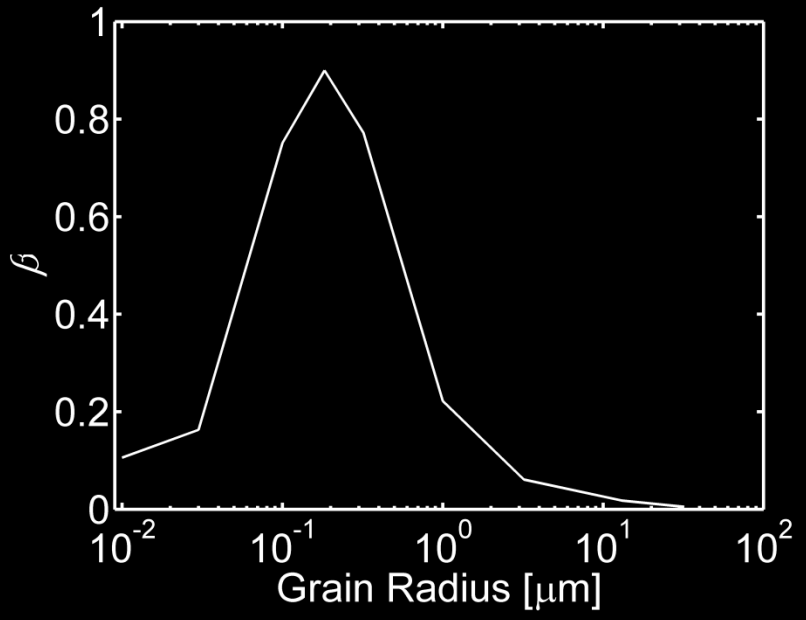
- Dust is effected by solar radiation pressure (SRP)

- Size of effect is determined by the lightness parameter

$$\beta = \frac{F_{SRP}}{F_g}$$

- Mass efficiency follows area-to-mass ratio

$$\propto \frac{1}{R}$$



L_1 Dust Cloud – Dynamics

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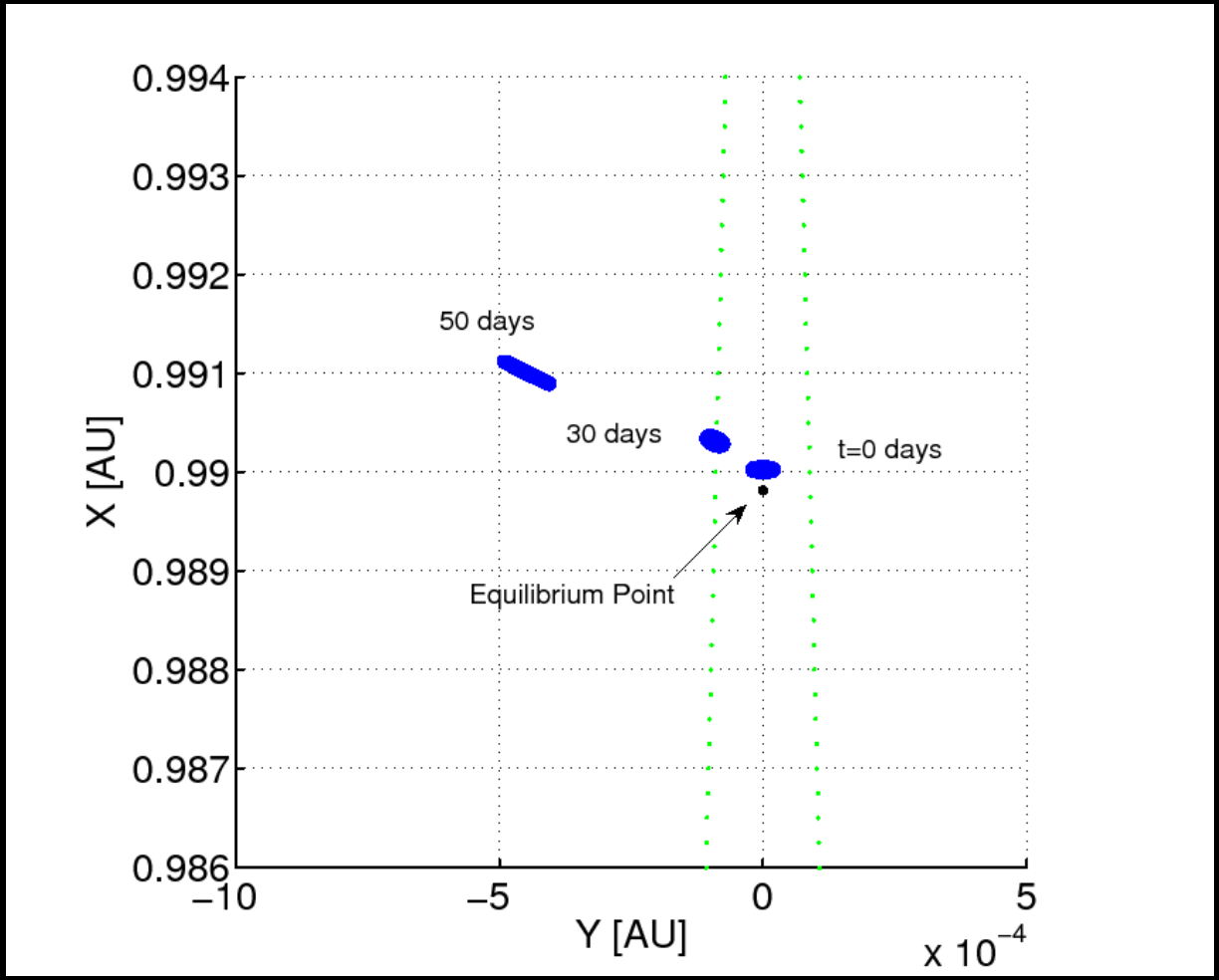
Fig. Motion of a dust cloud for grains with β=0.061



L_1 Cloud – Results

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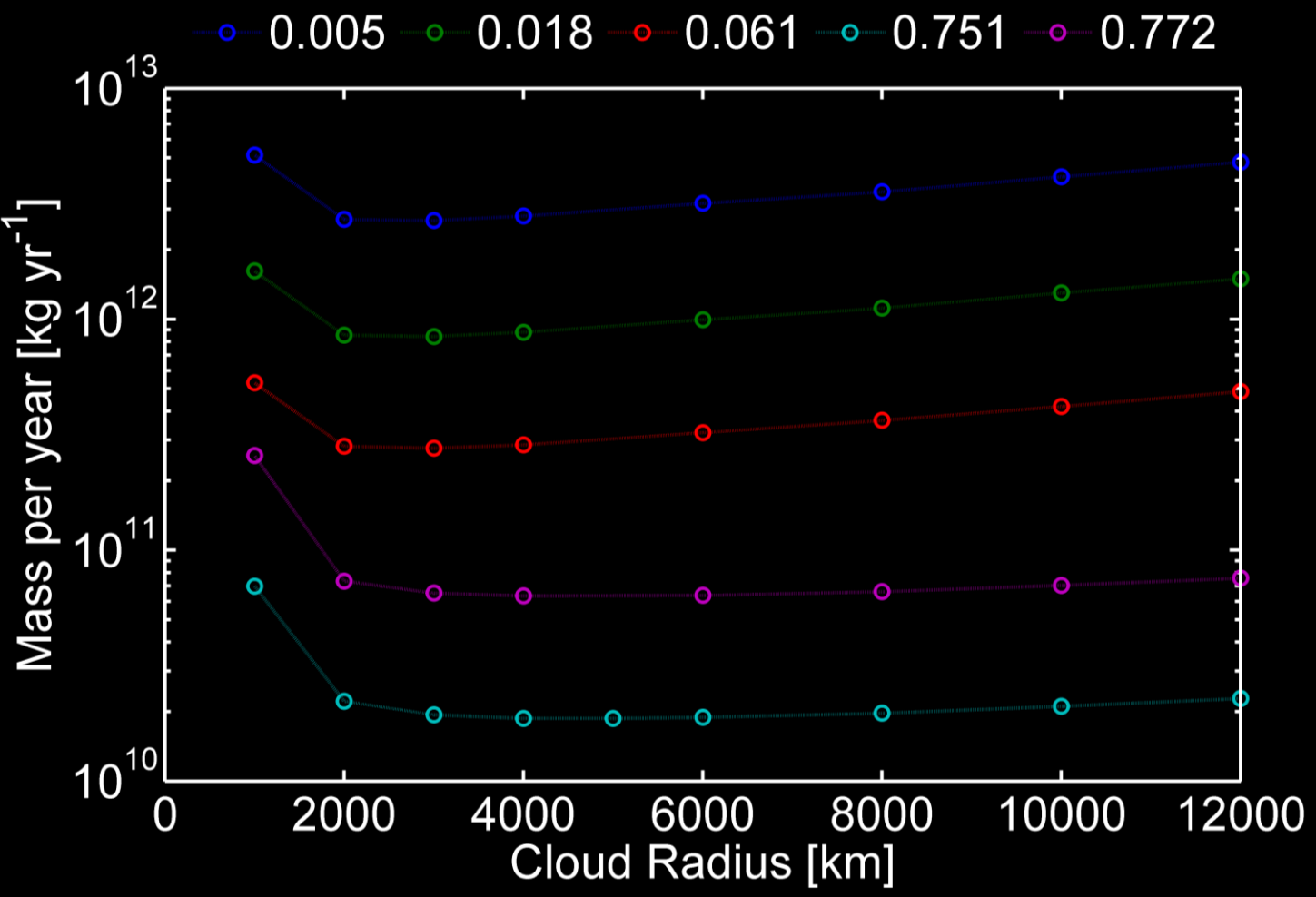
Fig. Mass required to achieve an insolation reduction of 1.7%



Earth ring system

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- Previously investigated by Pearson*
  - Mass = 10^{12} kg
  - Pearson's model did not include solar pressure and Earth oblateness
- This work approaches the concept from the point of view of high area-to-mass ratio orbital dynamics
- The dust ring will accumulate over time

*Pearson, J. et al. (2006). Earth rings for planetary environment control. Acta Astronautica 58(1): 44.

Reference frame

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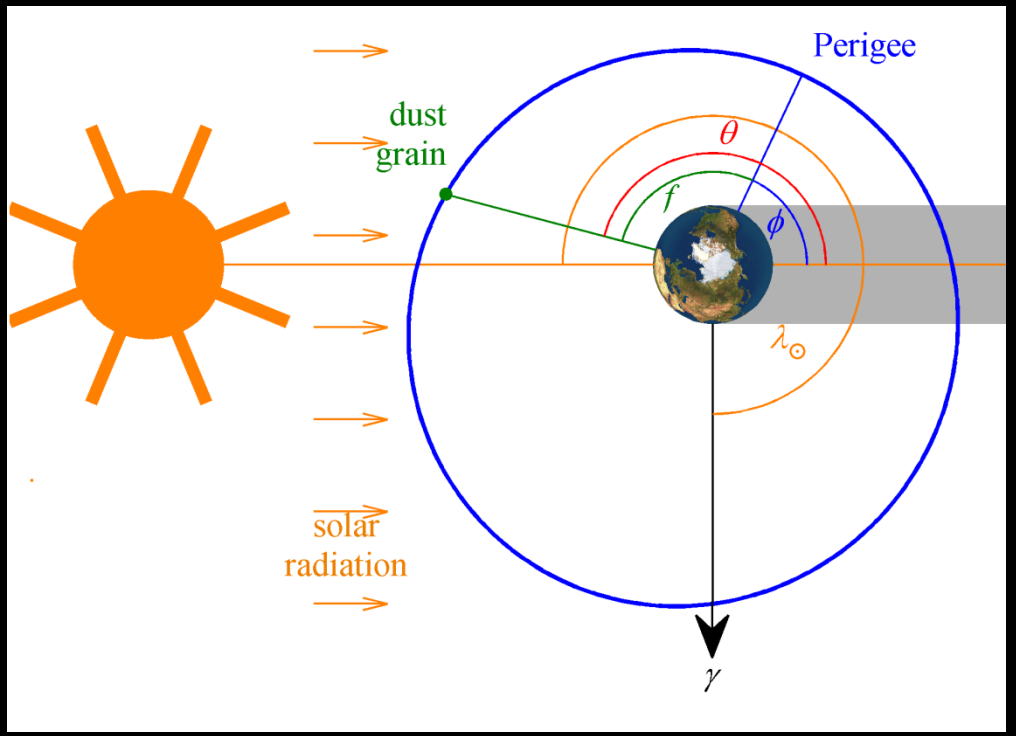
- Three parameters to describe planar orbit:
  - *a*, semi-major axis
  - ϕ, solar radiation-perigee angle
  - *e*, eccentricity
- Two ways of describing dust grain position
  - *f*, true anomaly
  - θ, anomaly with respect to the direction of solar radiation
- $\lambda_\odot$, position of the Sun



Orbital evolution of dust

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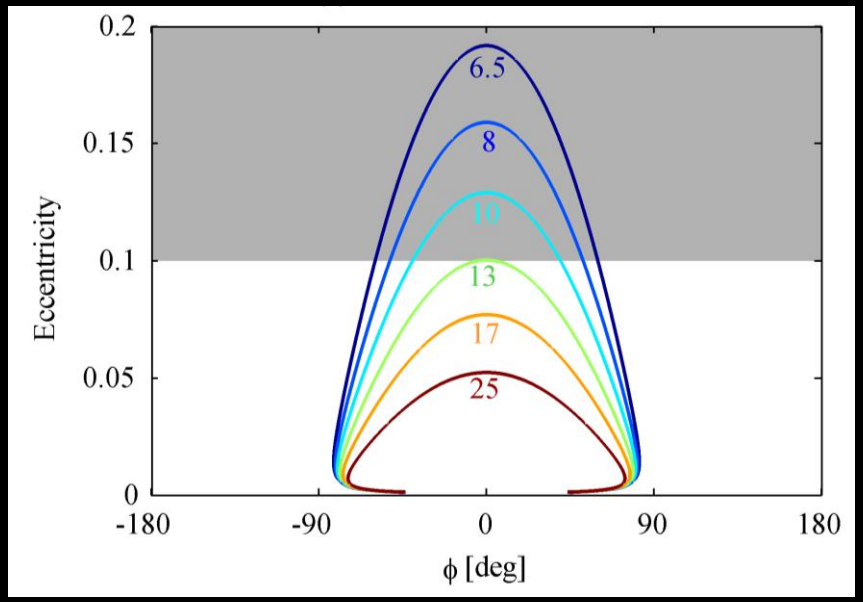
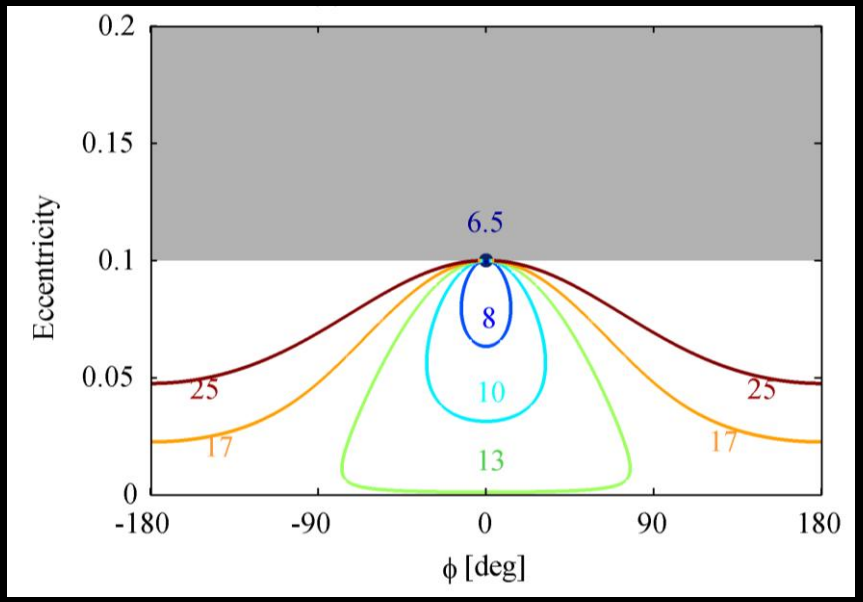
released in circular orbit



- grains smaller than 13 µm enter drag and decay.

released in eccentric orbit

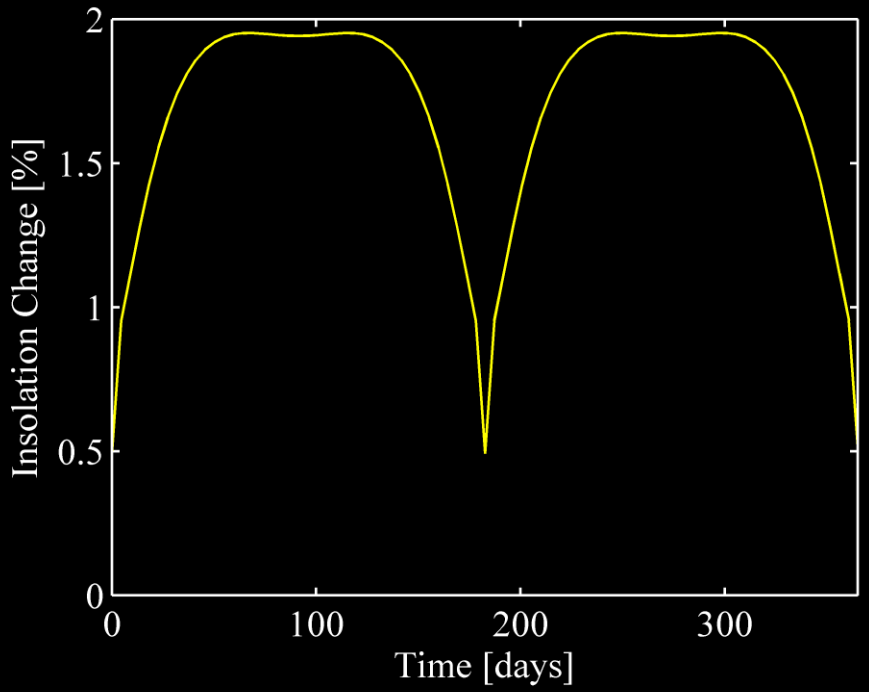


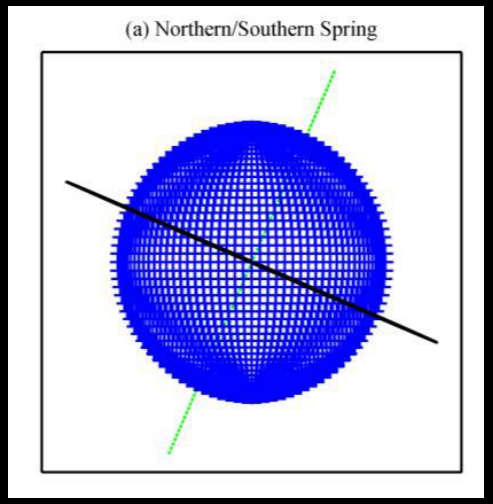
- grains smaller than 6.5 µm enter drag and decay.

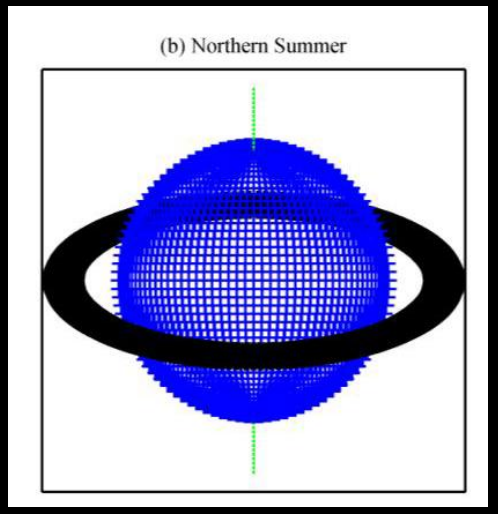
➔ **Release in eccentric orbit with Sun-pointing apogee needed.**

Insolation Change

System must take account of the tilt of Earth's axis







Insolation Change

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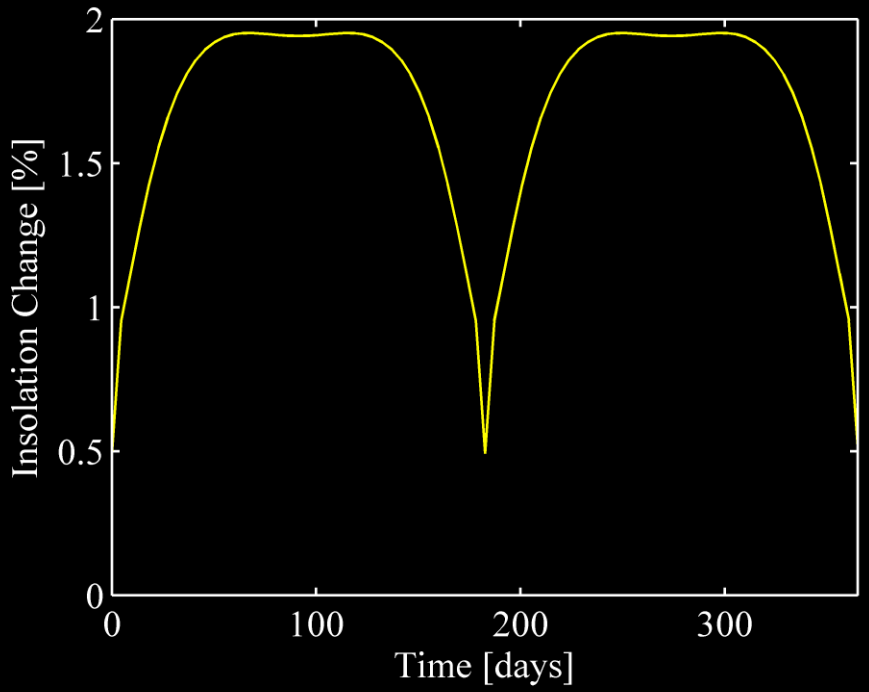
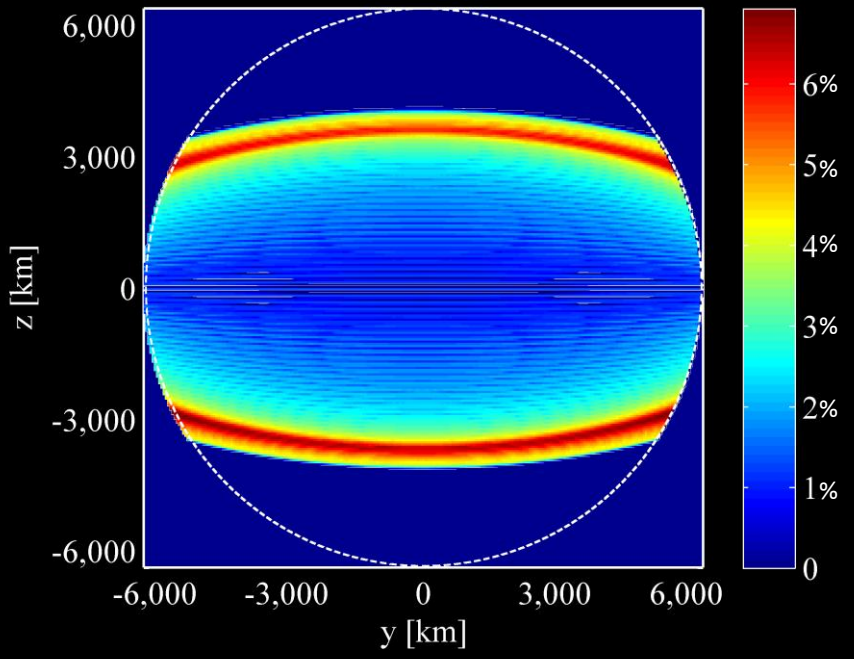
Average



Earth Disk



Mass Requirement

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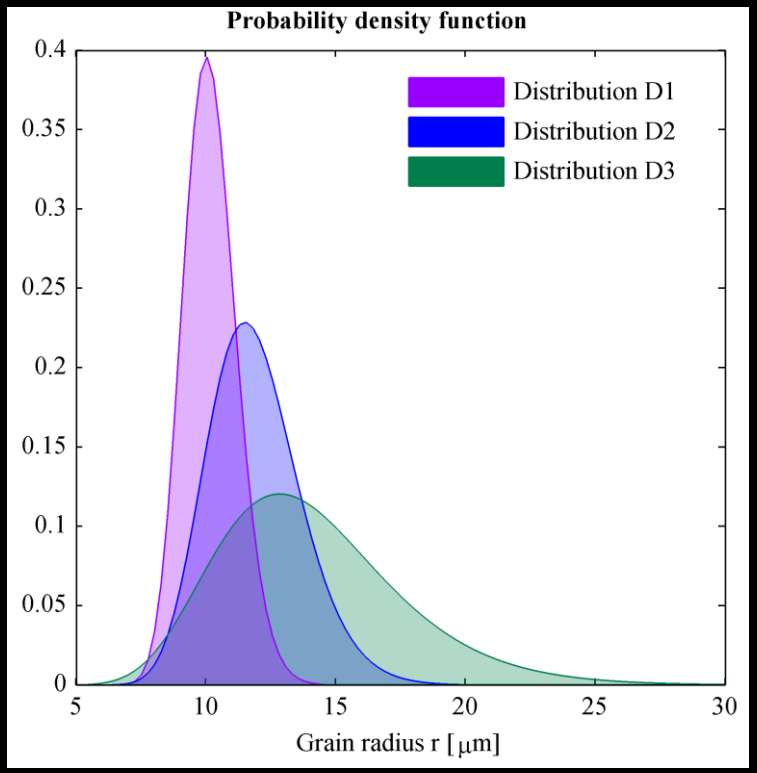
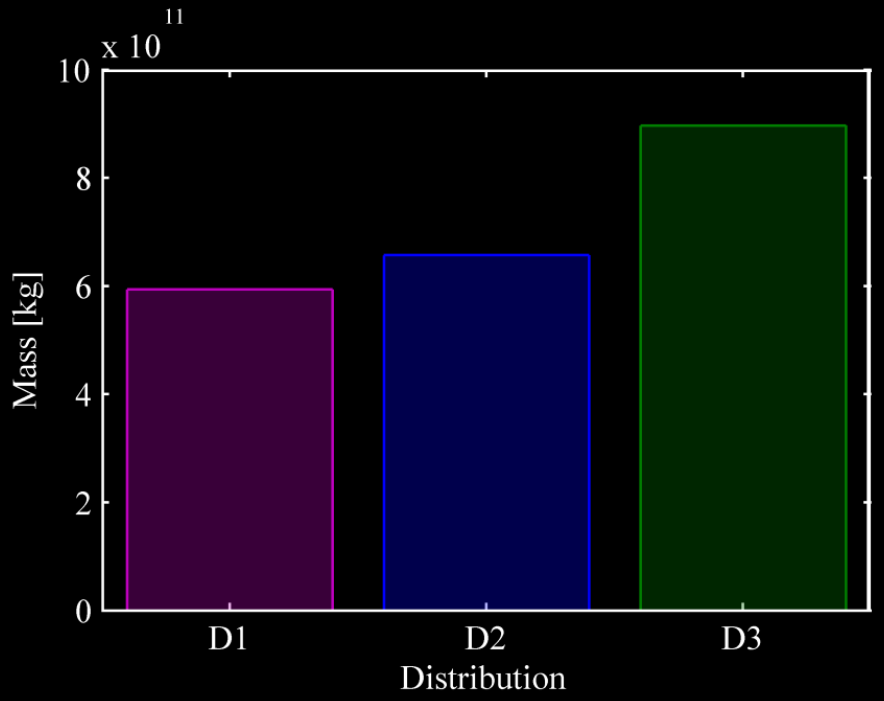
Dust distributions



Mass



Asteroid Material Availability

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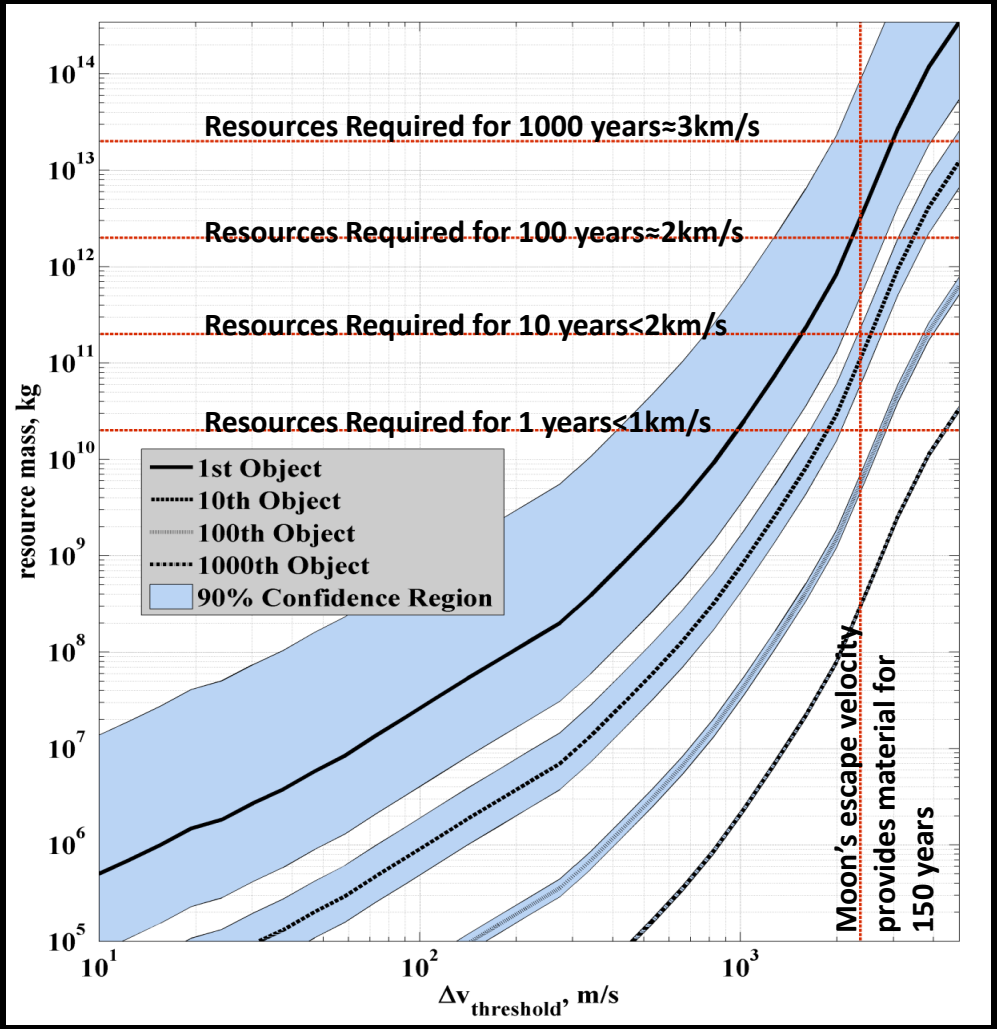

Sanchez, J.P. and McInnes, C., Accessibility of the resources of near Earth space using multi-impulse transfers, in *Astrodynamics Specialist Conference, 2010, AIAA, Toronto, Ontario, Canada*

THE POLITICAL ENVIRONMENT

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Important Questions

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- Should we deliberately modify the climate?
- Should we implement a global scheme without universal agreement?
- Should, or could, we prevent a country from taking unilateral action?

Current Status

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- Little global consensus on how to tackle climate change
- UN Moratorium on geo-engineering testing that threatens biodiversity
- First UK geo-engineering experiment postponed pending a review

Carbon Capture Methods

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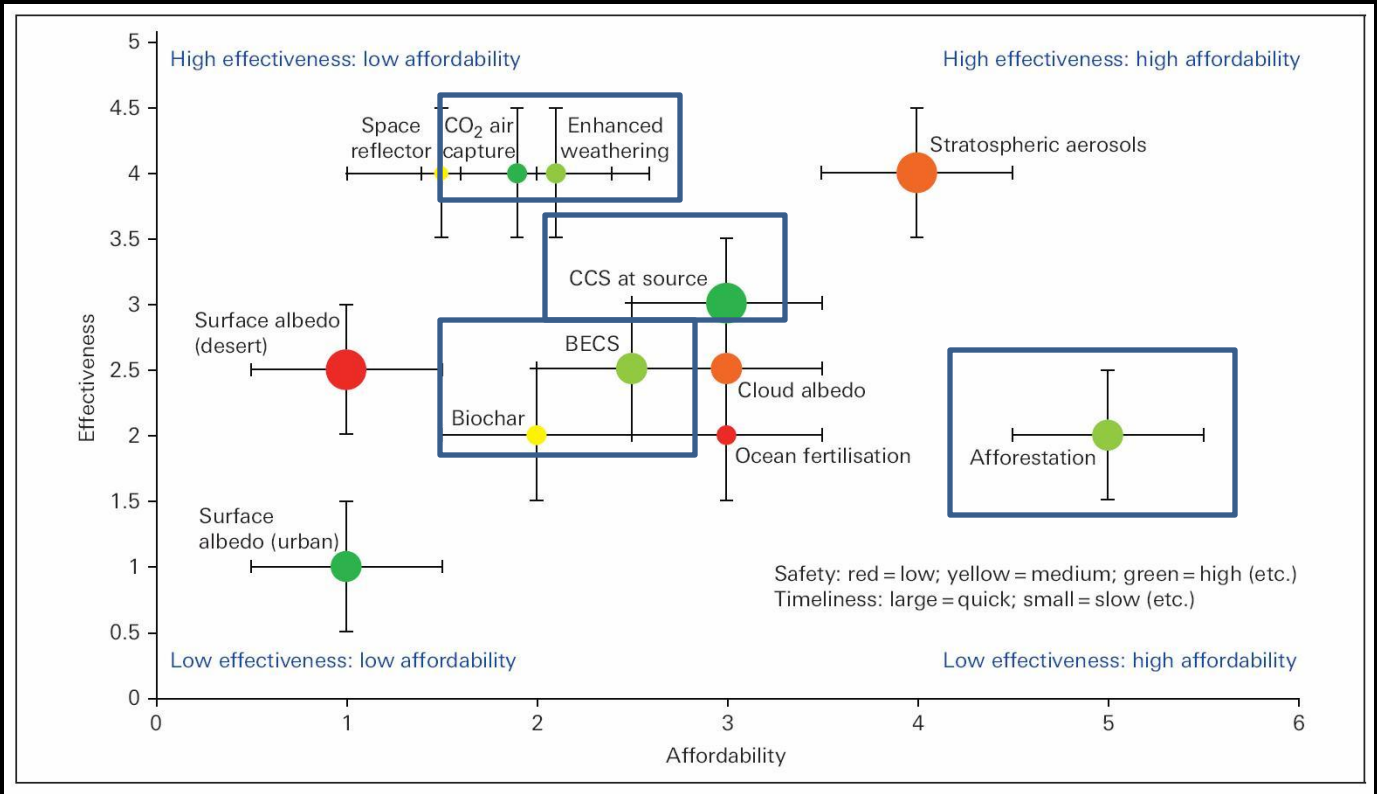
How much CO_2 do we want?



[2] – Shepherd at al. Geoengineering the climate , Report of Royal Society working group on geoengineering, 2009

SRM Methods

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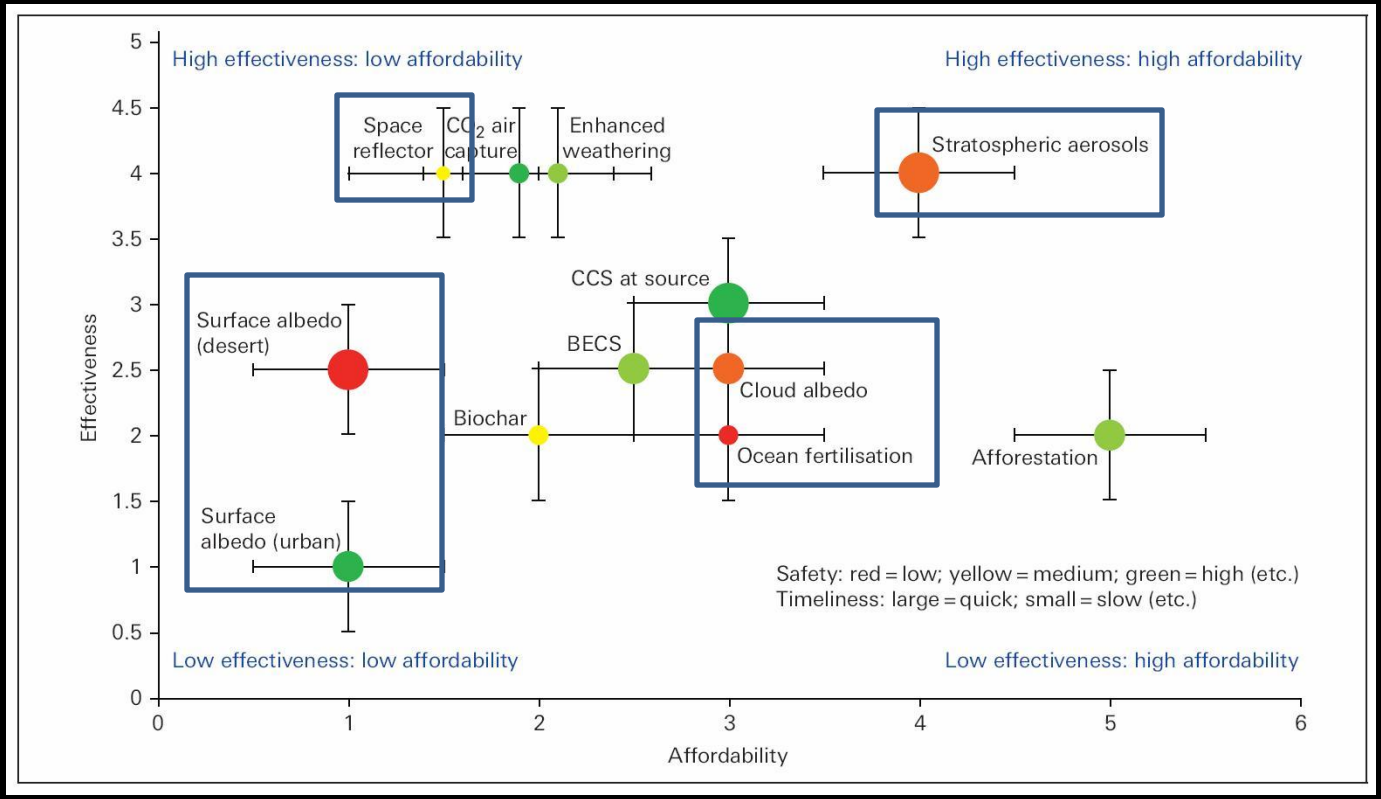
Can we agree which method to use?



Shepherd at al. Geoengineering the climate , Report of Royal Society working group on geoengineering, 2009

A COMBINED APPROACH

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A Combined Approach Example

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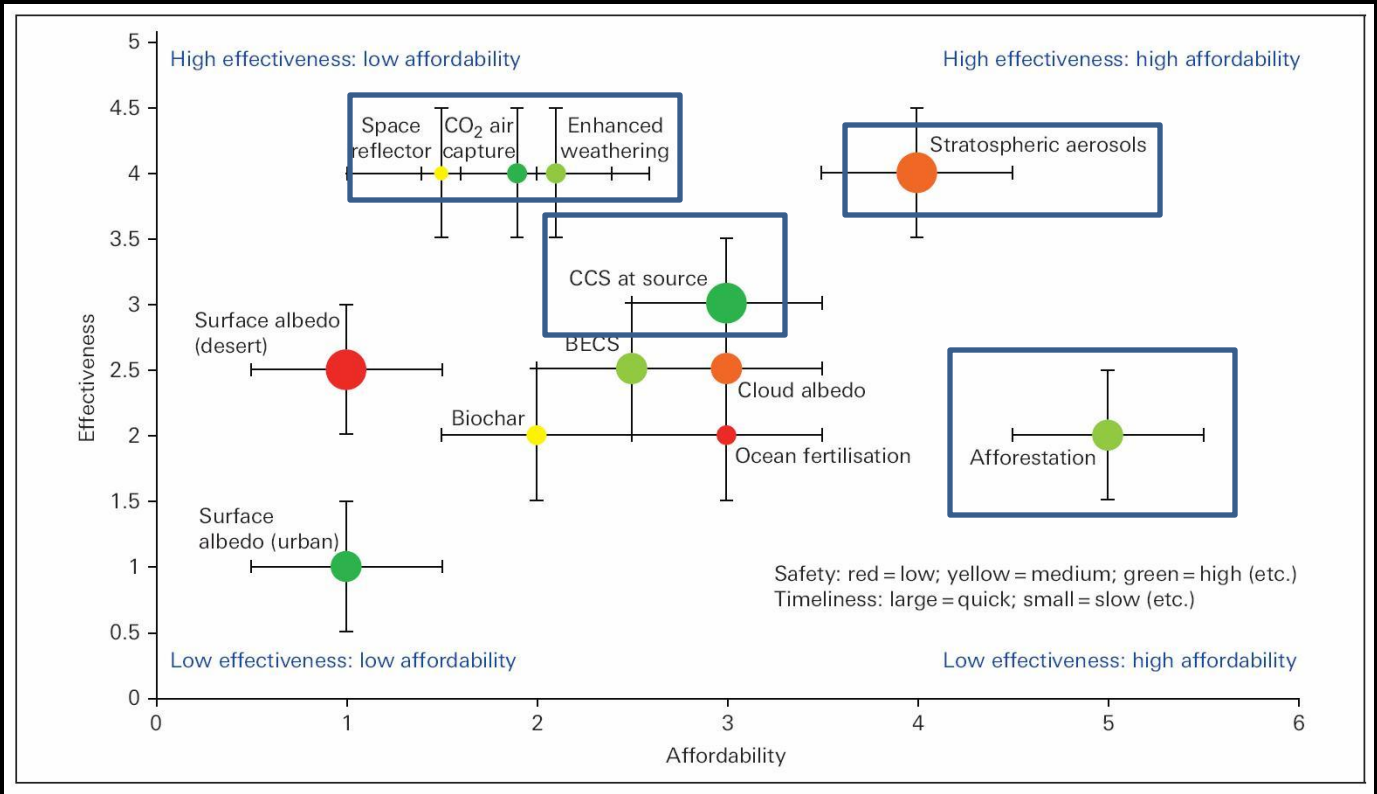
There is no silver bullet!



Shepherd at al. Geoengineering the climate , Report of Royal Society working group on geoengineering, 2009

CONCLUSION

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Conclusion

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- Space-based geo-engineering is an effective method of geo-engineering
- Dust cloud methods reduce the complexity of space-based geo-engineering methods
- There are many political challenges to implementing geo-engineering
- Geo-engineering cannot be used as a permanent remedy to climate change
- There are many unknowns regarding geo-engineering and more testing is required

Conclusion

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Thank You!
Any questions?

Thank you to ESA for their sponsorship to attend this workshop

Russell Bewick
russell.bewick@strath.ac.uk